



Review

Early motor skill competence as a mediator of child and adult physical activity

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ABSTRACT

Objective: In order to effectively promote physical activity (PA) during childhood, and across the lifespan, a better understanding of the role of early motor skill development on child and adult PA is needed. **Methods:** Here, we propose a conceptual model delineating the hypothesized influence of motor skill development on child and adult PA, while providing an overview of the current empirical research related to this model. **Results:** There is consistent and emerging evidence showing that adequate motor skill competence, particularly locomotor and gross motor skills, is associated with increased PA levels during the preschool, child, and adolescent years, with early motor skill development also influencing enjoyment of PA as well as long-term PA and motor skill performance. The physical education setting appears to be a well-suited environment for motor skill development. **Conclusion:** Employing appropriate strategies to target motor skill development across the childhood years is of paramount interest in helping shape children's PA behavior, their experiences related to PA, as well as maintain their PA.

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Introduction

The prevalence of child obesity has risen drastically over the last several decades, with this increased trajectory occurring worldwide

(Wang and Lobstein, 2006). Preventing obesity during early childhood is of particular importance, as young obese children are at an increased risk for adolescent and adult obesity (Veltsista et al., 2010; Telama, 2009) and have an increased risk of developing various health morbidities, including hyperlipidemia, hypertension, insulin resistance, respiratory problems, orthopedic complications, and cancer (Freedman et al., 1999; Fuemmeler et al., 2009; Craig et al., 2008). The Bogalusa Heart Study, a longitudinal study with over 2500 participants, reported 77% of overweight children became obese adults, as classed by body mass index (BMI) (Freedman et al., 2001).

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One such modifiable behavior to prevent and treat obesity at all age groups, along with the consequences linked with obesity, is regular participation in physical activity (Plachta-Danielzik et al., 2011; Loprinzi et al., 2012). Despite the importance of regular physical activity participation among children, studies employing objective measures of physical activity demonstrate that children are not engaging in sufficient levels of daily physical activity. For example, results from the 2003–2004 National Health and Nutrition Examination Survey indicate that, while employing an objective measure of physical activity, only 42% of American children (6–11 years) are meeting the current 60-minute moderate-to-vigorous physical activity recommendation, with 8% of adolescents (12–19 years) meeting this threshold (Troiano et al., 2008).

Given that the majority of children and adolescents are not sufficiently active, coupled with the beneficial effects of physical activity in these populations, promotion of physical activity is of critical importance during early childhood development. Numerous factors have been shown to influence child physical activity (e.g., parent and peer support, physical activity preferences, behavioral intentions, program/facility access) (Loprinzi et al., 2012; Sallis et al., 2000). However, and often overlooked, evidence suggests that motor skill acquisition in early childhood may be an important prerequisite for child physical activity participation and engagement in physical activity later in life (Loprinzi et al., 2012). Notably, adequate motor skill competence is also linked with improved cognitive, social and emotional outcomes (Piek et al., 2006, 2008; Skinner and Piek, 2001).

In order to effectively promote physical activity among children, a better understanding of the influence of motor skill development on child and adult physical activity is required, given evidence suggesting motor competence may lead to increased physical activity across the lifespan (Lloyd et al., 2014). Based on national standards for physical education guidelines, fundamental-related motor skills consist of locomotor, manipulative, and non-locomotor skills (such as balance). Locomotor skills consist of activities that result in some degree or horizontal and/or vertical displacement during translocation, which may include, for example, walking, running, jumping and skipping. Manipulative skills are often defined as gross or fine skills, which often include no movement-related translocation. Examples of gross motor skills include throwing, catching and kicking, with fine motor skills including, for example, fine precision object-handling activities. Notably, certain activities, such as throwing darts, may target both gross and fine motor skills. Lastly, individuals with balance-related motor skills have adequate postural stability during stationary body

movement (Gallahue and Cleland-Donnelly, 2007). To date, most of the studies examining the association of motor skill acquisition and physical activity have focused on locomotor and manipulative skills.

Fig. 1 presents a model delineating the hypothesized influence of motor skill development on child and adult physical activity. The overall goal of this review paper is not to provide an exhaustive quantitative review (i.e., systemic review) of the literature surrounding determinants of child physical activity, but rather to examine research assessing the links between the constructs proposed in our model. We acknowledge the direct link between physical education/sports and child physical activity, but the focus of this model and narrative review paper will center on the mediational influence of motor skill development and enjoyment of PA on physical activity behavior. This narrative review examines empirical research addressing the links in the proposed model and physical activity participation.

Overview of the proposed model

It is acknowledged that various psychosocial, cultural, and organizational factors may influence a young child's degree of participation in PE and, in particular, engagement in sports. Nevertheless, central to the proposed model (Fig. 1), PE and sports participation may directly influence child physical activity, as well as indirectly through improvements in perceived and actual motor skill development. Further, motor skill competence may indirectly influence physical activity through increased enjoyment of physical activity. Then, importantly, increased enjoyment and actual physical activity participation during early childhood may influence physical activity during later years (e.g., adolescents and adulthood). In this model we review, specifically, the effect early motor skill development has on PA participation, however, we do acknowledge a reciprocal relationship in that PA participation may help to cultivate motor skill acquisition.

Physical education/sports → child PA

Research has provided evidence that participation in physical education (PE) and sports may help facilitate child physical activity. Indeed, participation in sports has been shown to increase overall physical activity behavior among young individuals (Pfeiffer et al., 2006). Similarly, based on results from the U.S. National Longitudinal Study of Adolescent Health, adolescents were more active if they had daily physical education (Gordon-Larsen et al., 2000). However, as of 2006, only 3.8% of elementary schools, 7.9% of middle schools, and 2.1% of high schools

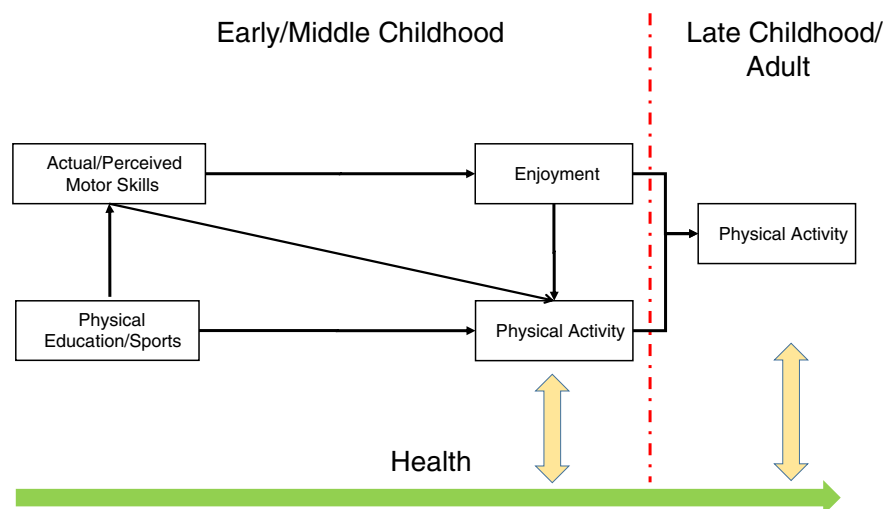


Fig. 1. Conceptual model delineating potential direct and indirect pathways of motor competence on child/adult physical activity.

offered students daily PE for the entire year (Lee et al., 2007). Effective programs designed to improve the quality of PE to increase the amount of time that children engage in moderate-to-vigorous physical activity include, for example, the Sports Play and Active Recreation for Kids (SPARK) curriculum (Dowda et al., 2005), the Child and Adolescent Trial for Cardiovascular Health (CATCH) program (Luepker et al., 1996), and the Lifestyle Education for Activity Program (LEAP) (Pate et al., 2005).

Physical education/sports → actual motor skills

Arguably, engagement in motor skill-related sports may have a profound beneficial effect in improving motor skills. Here, we'll focus on the effect of PE on motor skills as the PE setting may be well suited to develop children's motor skills given that most children attend school and PE teachers have been trained in the instruction of motor skill development.

School-based PE offers a great opportunity to ensure children have the necessary fundamental-related movement skills that may help to contribute to increased immediate and long-term physical activity. Regarding motor competence, the concept of physical literacy has been a key focus in development of PE curriculum. Physical literacy personifies the development of children's capacity to perceive intelligently and respond effectively to the physical demands encountered throughout daily life. This embodies more than simply physical movement of the body (Whitehead 1 M, 2001). Although studies have reported children's physical activity levels and motor skill performance during PE, surprisingly, few studies have examined the actual efficacy of PE in improving children's motor skills (Sallis and Saelens, 2000; Booth et al., 1999).

Encouragingly, there is some evidence to suggest that PE can indeed help improve fundamental-related movement skills, while at the same time not compromise participation in moderate-to-vigorous physical activity (van Beurden et al., 2003), which is an overarching objective in PE curriculum. Among a sample (7–10 years) of 9 control and 9 intervention schools in Australia, the *Move It Groove It* PE-based intervention employed various fundamental movement skill strategies to improve eight different locomotor and gross movement skills. The intervention resulted in substantial improvements in every assessed fundamental movement skills for both genders, ranging from a 7.2% to 25.7% improvement. The PE-based fundamental movement skill intervention not only improved motor competence, but importantly, it did not compromise PE-based time spent in moderate-to-vigorous physical activity. In fact, the intervention resulted in a 4.5% increase in moderate-to-vigorous physical activity and a 3% increase in vigorous-intensity physical activity.

Likewise, Cicović et al. (2015) provided evidence of PE's ability to improve motor skill competence. A sample of 65 male students (mean age 14 years ± 6 months) underwent a semester long experimental PE program to assess improvements in motor skill competence (Cicović et al., 2015). Nine tests of motor skills were used to assess motor competence. Statistically significant increases in motor competence were observed for 5 of the 9 motor tests, indicating the efficacy of PE classes in improving motor skill competence. Further study has also shown promising motor skill improvements as a result of PE class participation (Veličković, 2012).

Theoretically, self-determination theory proposes that intrinsic motivation stems from basic human needs to demonstrate competence, autonomy, and social relatedness, all of which can be achieved through the physical domain (Ryan and Deci, 2007). The PE environment affords children the opportunity to satisfy these needs through novel and challenging activities via competition among their counterparts. The curriculum of PE classes bases its physical activity, many times, in sport and gaming (which children may identify as inherently enjoyable) (Cumming et al., 2008) allowing for competition among children. This environment develops motor competence through its curriculum

while the nature of activities along with satisfaction of basic needs may promote enjoyment of physical activity behavior, thus establishing the PE environment as a vital component, not only in the development of motor skills but also developing an enjoyment of physical activity.

Actual motor skills → child PA

Prospective studies have linked early childhood motor competence to neurological development and future success in achievement domains (Pagani et al., 2010; Grissmer et al., 2010). Furthermore, over the last decade (2005 onward), research has more extensively started to investigate and demonstrate the importance of motor skill acquisition in facilitating and shaping physical activity behavior in the early childhood years. The narrative in this section will briefly summarize and synthesize this research. Although the majority of research presented here is cross-sectional in nature, these associations provide insight into possible links between motor skills and physical activity.

Preschool/early elementary

In a sample of U.S. preschool children (mean age 5 years), locomotor motor skills was associated with increased school-day pedometer-determined steps, but no association was observed for manipulative or perceived motor skill competence with accumulated steps (Robinson et al., 2012). Relatedly, in a sample of 4-year-olds from Finland, both locomotor and gross motor skills were associated with increased objectively-determined moderate-to-vigorous physical activity and light-to-vigorous physical activity (Iivonen et al., 2013), which is in alignment with a U.S. preschool study (mean age 4 years) utilizing accelerometer-determined physical activity data (Williams et al., 2008).

Middle school

In a sample of middle-school (grades 4–6) children from Canada, children who performed better on a locomotor-based obstacle course engaged in more free-living pedometer-determined steps (Larouche et al., 2013). In addition to free-living physical activity, and among a sample of children (8 years) from Australia, greater locomotor and gross motor skills was associated with increased total, lunchtime, recess, and after-school objectively-determined moderate-to-vigorous physical activity (Cohen et al., 2014). Similar results have been demonstrated in 6–9 year old girls from Canada (Bremer and Lloyd, nd). In a sample of children (7–12 years) from the Netherlands, children with and without intellectual disabilities who had greater gross motor skills were more likely to engage in sports (Westendorp et al., 2011).

High school

In a longitudinal study among adolescents from the Netherlands, self-reported physical activity was associated with improved manipulative (gross) and balance-related motor skills, but there was little evidence to support an association between fine-motor skills and self-reported physical activity behavior (Visser et al., 1998).

In addition to physical activity, there is also evidence exhibiting that, among children (8–9 years) and adolescents (17–18 years) from Canada, individuals with low motor competence, as determined by the Movement Assessment Battery for Children, have worse health-related fitness, specifically musculoskeletal fitness (Cantell et al., 2008). Similar findings have been demonstrated in Australian youth (Hands, 2008).

There is also evidence showing that motor skill acquisition in early childhood (6 years) is associated with higher levels of self-reported physical activity in early adulthood (26 years) (Lloyd et al., 2014). Similar longitudinal findings have been reported elsewhere (Barnett et al., 2009). In addition to the long-term effects of early motor skill development on follow-up physical activity behavior, additional evidence exists demonstrating that locomotor and gross motor skills may be maintained over time, particularly among girls (Zask et al., 2012).

Possibly explaining this significant link between actual motor skills and PA is the mediational role of perceived competence (Stodden et al., 2008; Barnett et al., 2011). Barnett et al (2008), using a prospective design, examined perceived sport competence as a mediator between actual motor skills and MVPA, as well as, cardiorespiratory fitness levels. Of 928 original intervention participants 276 completed at least one follow-up measure, 250 for the PA model and 227 for the fitness model. Perceived competence explained 18% ($R^2 = .18$) and 30% ($R^2 = .30$) of the variation in outcome measure for the PA model and the fitness model, respectively (Barnett et al., 2008).

Actual motor skills → enjoyment of PA

It is plausible to suggest that enjoyment of physical activity may mediate the relationship between motor skill development and child physical activity. Unfortunately, few studies have examined this specific potential mediational effect. Providing some evidence of this assertion, Fu et al. (2013) demonstrated that a health-related physical fitness intervention (including motor skill activities), compared to a traditional PE comparison group, was more effective at increasing the child's (mean age 12.6 years) perceived competence and enjoyment of physical activity. Thus, and although future research on this topic is needed, these preliminary findings suggest that effectively developing children's motor skills may influence their physical activity through improvements in affect-related areas, such as their perceived competence and enjoyment of the physical activity.

From a theoretical perspective, one could postulate as to correlations between motor competence and enjoyment of physical activity, as well as factors contributing to the mediational effect of physical activity enjoyment on the relationship between actual motor skills and future physical activity behavior. For example, Bandura's Self-Efficacy Theory proposes that specific sources of self-efficacy to engage in physical activity behavior develop out of past performance of a given behavior and the resulting affective states due to the behavioral engagement. A higher level of actual motor skill competence due to the performance of past physical activity behavior (motor skills) should result in greater self-efficacy for future behavioral performance, thus leading to heightened perceived competence regarding physical activity behavior. Also, higher perceptions as to one's ability to execute physical activity behavior may lead to positive affect (attitudes including enjoyment) regarding the behavioral engagement and ultimately greater propensity to engage in future physical activity. These factors are evidenced in the Lifestyle Education for Activity Program (LEAP) where self-efficacy and enjoyment of physical activity contributed to higher levels of physical activity among high school girls (Dishman et al., 2005).

Additionally, the Theory of Planned Behavior (Fishbein and Ajzen, 1975) posits that intention to engage in a future behavior is in part regulated by attitudes toward the behavior. Therefore, perceived enjoyment of physical activity (affective attitude) should increase the intention to participate in future physical activity behavior. The effect of affective attitude on behavior has been seen in an intervention study (Conner et al., 2011).

Enjoyment of child PA → late childhood/adult PA

Surprisingly, examination substantiating the transfer of enjoyment of child physical activity into adult physical activity participation is, thus far, lacking. As such, little research has examined whether enjoyment of physical activity during childhood is a predictor of adult physical activity behavior. However, we do know that various child-level psychological, cognitive, and emotional factors, such as attitude and enjoyment of child physical activity is associated with child physical activity (Sallis et al., 2000), and child physical activity tracks over time (Telama et al., 1997). The relationship between enjoyment of physical activity behavior and participation in physical activity in children shows that those who enjoy participation are more physically active

than those who do not enjoy the behavior. Carroll and Loumidis (2001) showed that students who enjoyed engagement in PE classes were more active outside of school than their counterparts who did not when objectively compared via accelerometry (Carroll and Loumidis, 2001). As well, evidence suggests intrinsic motives for physical activity engagement (i.e. enjoyment) to be associated with sustainable physical activity behavior (Ingledeew et al., 1998).

Relatedly, recent (2013) research demonstrates that affect-related experiences of physical activity in the early childhood years is a predictor of physical activity later in life (Cardinal et al., 2013). 293 U.S. undergraduate students (mean age: 20.7 years) from 20 different majors completed a questionnaire assessing their current physical activity levels as well as their experiences regarding *whether they ever tried out for a team and were cut; whether they had ever been picked or chosen last for a team; and whether they were not given the opportunity to play when on a team*. Regardless of gender, neither "having been cut from a team" nor "having been on a team but not played much" was associated with their adult physical activity behavior. However, those who said they had "been picked or chosen last for a team" engaged in less adult physical activity behavior.

This suggests that certain PE or sport-related practices, such as having students or athletes (e.g., captains) pick their team may be inappropriate and have long-lasting effects. Unfortunately, approximately 71.4% of PE teachers report *never* employing this strategy (Strand and Bender, 2011), and 31% of students report being picked last during PE (Cardinal et al., 2013). Thus, it is strongly encouraged that PE teachers not employ such a 'pecking order' approach as it may be detrimental to the student's psyche and ultimately, their immediate and future physical activity behavior by way of affect-related (enjoyment) factors pertaining to physical activity.

Early child PA → late childhood/adult PA

The Cardiovascular Risk in Young Finns study (Telama et al., 1997) examined whether physical activity behavior 'tracks' over time. Children age 9, 12, 15, and 18 years were followed at 3-year intervals for 9–12 years. Physical activity correlations across the time periods were generally moderate, with the highest correlations for 3-year intervals and declining as the time interval increased, suggesting strong physical activity tracking over shorter periods of time (<3-years). Other studies report similar findings (Telama et al., 2005). Research also demonstrates that physical activity tracks during the early child years (i.e., preschool age) (Pate et al., 1996). Not only does physical activity appear to track over time, but outcomes associated with physical activity (e.g., weight status) also appear to track from early to late childhood (Wang et al., 2000), and even into adulthood (Guo et al., 2000).

Given that physical activity (and its correlates [e.g., weight status]) and motor skills track over time, coupled with the fact that motor skill acquisition plays an important role in shaping child physical activity, early intervention to develop motor skills in early childhood is urgently needed.

Summary of findings related to the proposed model

There is consistent and emerging evidence showing that adequate motor skill competence, particularly locomotor and gross motor skills, is associated with increased physical activity levels during the preschool, child, and adolescent years, with early motor skill development also influencing enjoyment of physical activity as well as long-term physical activity and motor skill performance. Consequently, employing appropriate strategies to target motor skill development across the childhood years is of paramount interest in helping shape children's physical activity behavior, their experiences related to physical activity, as well as maintain their physical activity levels given that physical activity behavior tracks over time. A well suited setting to accomplish

this is during school-based PE. Indeed, research demonstrates that PE can help improve fundamental-related movement skills, while at the same time not compromise participation in moderate-to-vigorous physical activity (van Beurden et al., 2003).

There is great potential to improve fundamental-related movement skills as, in a sample of Australian children (grades 3–4), less than 50% were rated at mastery (21.3%) or near mastery (25.7) level (van Beurden et al., 2002). Thus, the PE setting may be well suited to help develop children's motor competence, which may require gender-specific games, equipment and spaces (Hardy et al., 2010). Not only should actual motor skill development be targeted in this setting, but efforts should be made to improve perceived motor skill competence, as there is evidence showing that perceived motor competence mediates the relationship between actual motor skill competence and subsequent development of physical activity (Barnett et al., 2008). This perception of motor skill competence may, in fact, lead to heightened enjoyment of physical activity behavior, which is associated with higher levels of physical activity currently and possibly through the lifespan (Carroll and Loumidis, 2001; Cardinal et al., 2013).

Future research should attempt to test the proposed model for its ability to predict physical activity behavior. It has been suggested that weight status may moderate the relationship between variables in the proposed model (Cawley and Spiess, 2008; Lopes et al., 2012; Jones et al., 2010), therefore, when testing this model it may be fruitful to examine how certain individual factors influence the relationships presented. Further, it is equally important for future studies to refine existing and develop enhanced tools to assess children's motor skills because of the proposed links between motor skills and physical activity behavior.

Conflicts of interest statement

The authors declare no conflicts of interest. No funding was used to prepare this manuscript.

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